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(54) Induction apparatus for air distribution system.

(57) An induction apparatus (10) for an air distribution system. A nozzle (12) is coupled with a primary air supply duct (18) downstream of a variable volume terminal unit to increase the velocity of air discharged from the duct (18). The increased primary air velocity induces secondary air into the primary air stream. The secondary air is supplied by a ceiling plenum which may be in communication with the conditioned area. A mixing chamber (14) is positioned downstream of the nozzle (26) and is sized for allowing mixing of the induce secondary return air with the primary air stream. A diffuser (20) coupled with the downstream end of the mixing chamber (14) distributes the mixed air into the conditioned space.

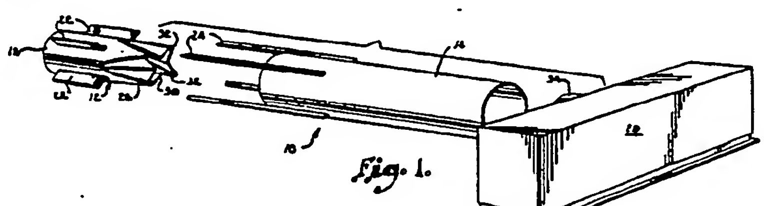

Fig. 1.

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INDUCTION APPARATUS FOR AIR DISTRIBUTION SYSTEM

This invention relates in general to the field of air conditioning systems and deals more particularly with an induction type air distribution system and method for using same.

Large buildings typically employ air distribution ducts which extend throughout the building for circulating conditioned air to heat and cool the interior thereof. Air used to cool the building is generally supplied at a temperature of approximately 55° F. Flow control devices are often used with the distribution system to allow the flow of conditioned air into each room or region of the building to be individually controlled. The flow control devices may be coupled with either the circulating ducts or the air diffusers which discharge the conditioned air into the individual rooms.

These types of variable volume distribution systems have several potential deficiencies. Because the conditioned air is delivered at 55° F the air shafts and duct work in the building must be of a relatively large size to supply the volume of air required to provide temperature or thermal conditioning of the individual rooms of the building. This reduces the building area available for office space or other types of usable areas. In order to move the large volume of air required and to compensate for pressure loss in the system, a large central fan and motor must be utilized to provide the necessary pressure. This size equipment necessarily results in relatively high initial cost and ongoing energy consumption and operating expenses for conventional variable air volume systems.

These systems must also be designed with sufficient air delivery capability to satisfy building code requirements and to achieve the desired air distribution and quality. While delivery of a quantity of conditioned air to a room may be adequate to provide the required heating or cooling, an inadequate distribution of the conditioned air within the room may cause significant temperature variations to occur. In addition to thermal conditioning, the distribution system must supply contaminants and otherwise condition the air in the room.

It has been found that the quantity of air required for thermal conditioning may be reduced in some air distribution systems if lower temperature conditioned air is utilized. While the use of low temperature air allows for the use of smaller sized ducts, the reduced quantity of air is often inadequate to provide proper distribution and secondary air motion in the conditioned space necessary for maintaining uniform temperature and proper air quality. The lower air temperature also presents a problem in that the conditioned air has a greater density which creates objectionable cold air down drafts within the conditioned space. These problems generally occur when the room temperature is such that only small quantities of conditioned air are required. Under these reduced thermal load conditions, the reduced quantities of conditioning air fail to follow the designed air flow distribution patterns resulting in the cold air falling directly on the occupant of the room.

Various methods of mixing the cold supply air with a source of warm room or return air have been employed in an attempt to provide a solution to these problems. One method employs a terminal unit in combination with a fan which mixes the cold supply air with ceiling plenum air before the supply air is distributed to the room. While this method provides for adequate mixing of the supply and return air, it often increases the energy requirements of the overall system by introducing a less efficient fan in the terminal unit. The installation cost of the system is also increased because of the additional cost of the electrical installation and controls and it may introduce objectionable noise above the conditioned space.

A high pressure induction system has also been utilized for mixing cold primary or supply air with warmer room return air. The system uses an induction terminal device which uses the primary air velocity to induce secondary air from a ceiling return plenum to create a mixed air supply which is distributed into the room by diffusers. However, it is undesirable in the induction system to have a pressure more than about 0.3 inch W.G. in the secondary air path of downstream from the point where the cold primary air and the secondary air are mixed because the induction effect degrades rapidly with increasing pressure. The system also requires significantly higher fan static pressure from the main supply system which creates noise problems requiring acoustical attenuation. The induction performance may also be significantly reduced if the system design or installation is improper and increased pressure drop occurs. Further, the necessary conditioning air may not enter the space at all in such circumstances. There are many opportunities for pressure loss to inadvertently be introduced in the system and extensive and costly modifications may be required after installation in order to achieve design performance. In addition to inadequate induction performance, the system may even cause cold air to be dumped into the room through the return plenum.

Another type of induction system has been suggested which utilizes diffusers for inducing return air at the point of distribution into the room. In

addition to excessive noise levels, this type of system presents many design problems for achieving proper diffusion and is an undesirable way of accomplishing the desired goal.

It is a primary object of this invention to provide an induction system for distribution of conditioned air which does not require significantly higher system pressure to achieve the desired induction and mixing of a primary air stream with secondary air prior to distribution of the mixed air stream into a conditioned area.

It is another object of this invention to provide an induction system for mixing a primary air stream with secondary air without the need for acoustical attenuation of the system at the point of distribution of the mixed air stream into a conditioned area.

It is a further object of this invention to provide an induction system which provides a relatively constant ratio of primary and secondary in the mixed air stream across a range of primary air stream flow rates so that the desired air flow distribution in the conditioned area may be maintained under varying load conditions.

To accomplish these and other related objects of the invention, an induction apparatus is provided for mixing the primary air stream and secondary air prior to distribution through a room diffuser. The apparatus comprises a nozzle for coupling with a downstream end portion of an air duct which carries the primary air stream from its source and axially aligned chamber for mixing the primary and secondary air. The chamber has an upstream portion with a larger cross-sectional area than the nozzle discharge end. The discharge end of the nozzle has a reduced cross-sectional area in relation to the primary air duct for increasing the rate of flow of the primary air stream with an acceptable pressure drop across the nozzle. The increased rate of primary air flow induces secondary air flow into the primary air stream. The primary air stream and induced secondary air are then directed to the chamber where mixing occurs prior to the distribution in the room. As a result, the desired conditioning air distribution may be obtained without the disadvantages associated with conventional air distribution systems.

In the accompanying drawings in which like reference numerals are used to indicate like parts in the various views:

Fig. 1 is an exploded perspective view of an induction apparatus of the present invention and a room diffuser;

Fig. 2 is a side elevational view of the induction system shown in fig. 1 with portions broken anway for purposes of illustration; and

Fig. 3 is a view taken in vertical section along line 3 - 3 of Fig. 2.

Referring now to the drawings in greater detail, an induction apparatus of the present invention is represented generally by the numeral 10. The apparatus 10 is used with an air distribution system to provide thermal and other conditioning of air within a structure such as a large commercial building. The induction apparatus comprises a nozzle element 12 which is aligned at a downstream end with a mixing chamber 14. The upstream end 16 of nozzle element 12 is coupled with a primary air supply duct 18 which carries conditioned air from a central fan. A controlling terminal unit (not shown) coupled with a room thermostat may be positioned in duct 18 upstream from the element 12 to meter the required quantity and/or temperature of primary air to the induction apparatus. The downstream end of chamber 14 is coupled with diffuser 20 which distributes conditioned air into a room or area in the building.

Nozzle element 12 comprises an elongated open-ended duct having a cylindrical main body portion 21 sized to approximate the cross-sectional area of duct 18. A series of radial fins 22 are mounted on the outer surface of body portion 21 for coupling with similar attachment fins 24 which are mounted on the outer surface of chamber 14 and extend longitudinally from the upstream edge of the chamber. Members 22 and 24 may be connected by welding or other suitable means to place element 12 and chamber 14 in axial alignment with the desired longitudinal distance of separation between the element and chamber.

The downstream end portion of nozzle element 12 is formed into a discharge nozzle 26. The nozzle 26 tapers uniformly from the cross-sectional area of the main cylindrical portion 21 to a reduced cross-sectional area at a discharge end 30 of the nozzle. As can best be seen in Fig. 3, the discharge end of the nozzle is formed into a generally four-legged star configuration, with each leg of the star having an arcuate rather than a pointed end portion 32. The circumferential dimension of the nozzle at the discharge end is substantially the same as that at the main cylindrical portion.

Chamber 14 has an elongated generally cylindrical shape and has a larger cross-sectional area than nozzle element 12 and nozzle 26. As will be subsequently discussed, the cross-sectional area and length of chamber 14 are sized in relation to nozzle 26 to achieve specific desired results. The downstream end of the chamber is connected to a mounting collar 34 of room diffuser 20. Diffuser 20 is but one of the various types of diffusers which may be utilized with the apparatus of this invention.

In operation, a primary srream of conditioned

air is supplied from the central fan through primary air duct 18. The temperature of the conditioned air may be varied and when used in cooling applications may be as low as approximately 42° F. In general, a conditioned air temperature below 50° F is preferred because it allows a significant reduction in the size of the air handling component. It is to be understood, of course, that the conditioned air may be used for heating rather than cooling purposes. The quantity of air delivered to the nozzle element 12 is preferably regulated by a variable volume terminal unit positioned upstream of the nozzle element in duct 18. A room mounted thermostat coupled with the terminal unit supplies the required thermal information for determining the appropriate quantity of conditioned air supplied by the terminal unit.

As the primary air stream flows through nozzle 26, the gradually decreasing cross-sectional area in the nozzle available for flow causes the flow rate to increase. This increased flow rate at the discharge end of the nozzle results in induction of secondary air into the primary air circumference of the nozzle and the inner circumference of the chamber. As the primary air and secondary air travel through chamber 14 they mix to form a conditioned air stream having a moderated temperature which is then discharged into the room through diffuser 20.

In selecting the shape of nozzle 26, consideration must be given to the induction effect desired. To achieve a larger induction factor (defined as the ratio of induced air volume to primary air volume), it is necessary to increase the surface area of contact between the induced air and the primary air by reducing the cross-sectional area available for flow while increasing the circumferential dimension of that cross-sectional area.

As an example, a cone shaped nozzle having the same cross-sectional area available for flow as nozzle 26 would necessarily have a smaller circumferential dimension and less surface area of contact between the induced air and primary air. The cone shaped nozzle would thus have a smaller induction factor at the corresponding flow rates. At the same time that the surface area of contact increases, the pressure drip across the nozzle increases. Excessive pressure drop is undesirable as it requires that the central fan be sized to supply additional pressure to the system. Thus, the nozzle must be designed to maximize the induction factor within acceptable pressure drop limits. It has been found that the nozzle 26 configuration produces a desired induction factor with an acceptable pressure drop of approximately 0.3 - 0.5" W.G. It has also been found that the arcuate or curvilinear ends 32 of the legs produce a lower pressure drop than legs having ends which are pointed or have a smaller radius of curvature.

In selecting a nozzle shape it is also important to select a configuration which will produce a relatively constant induction factor at varying primary air stream flow rates. A constant induction factor allows the designed air distribution within the conditioned space or room to be maintained even though the flow rate of the conditioning air varies significantly in response to variations in the thermal load. As an example, a slot type diffuser such as diffuser 20 directs a high velocity stream of conditioned air into the room along a flow path which travels generally parallel to the ceiling. This flow pattern results from the negative static pressure between the flow path and ceiling created by the velocity pressure. The negative static pressure holds the air stream to the ceiling and entrains large amounts of room air, resulting in a mixing of conditioned air with room air without objectionable drafts. A nozzle which produces a varying induction factor would cause the temperature of the conditioned air discharged by the diffuser to vary depending upon the primary air flow volume. At low flow volumes the discharge air would tend to be at a lower temperature because of inadequate mixing of the cold primary air with secondary return air. The discharged air thus has a greater density and its flow path may deviate from the prallel flow desired, creating cold down drafts as well as sweating of the diffuser. It has been found that the configuration of nozzle 26 produces a substantially constant induction factor across a range of flow rates and these potential problems have been avoided. It is to be understood, of course, that other nozzle configurations which satisfy these design considerations may also be utilized.

The nozzle discharge end 30 extends within the upstream end of chamber 14 but the relative longitudinal positioning of the nozzle and chamber may be varied for particular applications. For example, test runs have indicated that the discharge end of the nozzle and the upstream end of the chamber can be longitudinally spaced apart rather than oriented with the nozzle extending into the chamber. The optimal spacing of the nozzle and chamber should be determined in conjuction with other design parameters.

The difference in cross-sectional area between the chamber 14 and nozzle 12 is also an important design variable. The annular area representing the difference between the outer circumference of the nozzle and the inner circumference of the chamber affects the pressure drop in the system and the induction of secondary air into the primary air stream. The secondary air flows from the room and into the ceiling plenum through return air grills positioned in the ceiling. The ceiling plenum typically comprises the region above a dropped ceiling although return ducts may be used. If the annular

area is too small then the resistance to induction increases and the system performance is reduced. If the nozzle is longitudinally displaced from the chamber, the area of primary concern is that surrounding the circumferential area of the discharged primary air stream.

The chamber 14 must have a length sufficient to provide for adequate mixing of the primary and secondary air without producing excessive pressure drop within the chamber. The chamber must also be of a sufficient length in relation to the conditioned air stream velocity to prevent the air stream from impacting the room diffuser at a speed which will create rebound turbulence and increase the system pressure loss. In applications where the downstream end of the chamber has an oval rather than cylindrical shape, the chamber must have sufficient length to provide a smooth transition between the shapes.

While system performance is sensitive to the pressure differential between the room diffuser and the return air plenum, pressure drop upstream from the nozzle does not adversely affect performance. An additional benefit resulting from the positioning of the induction device directly upstream of the diffuser is the ease with which downstream pressure differentials may be adjusted by simply regulating the size or location of the ceiling return air grills. Downstream pressure problems in conventional terminal induction systems are not as easily remedied when the pressure drop is created by improperly installed downstream ducts. Portions of the ceiling and lighting fixtures typically must be torn down and the ducts reworked to achieve the designed pressure drop.

It can thus be seen that the apparatus of the present invention allows efficient mixing of primary conditioned air with secondary return air with reduced energy consumption. The mixing of primary and secondary air is maintained over a range of flow rates and provides the desired thermal distribution from the room diffuser without objectionable drafts or sweating of the diffuser. The performance of the induction apparatus is unaffected by the pressure drop in the primary air duct connecting the apparatus with the variable volume terminal unit as the apparatus is mounted directly upstream from the diffuser. In addition, induction is accomplished at very low noise levels and does not present a distraction to the room occupant.

From the foregoing, it will be seen that this invention is one well adapted to attain all the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

Since many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Claims

1. Induction apparatus (10) for mixing a primary air stream carried by a primary air duct (18) with secondary air prior to distribution of the mixed air into a room or building area, said apparatus (10) comprising:
a nozzle (12) coupling at a downstream end of said primary air duct (18) carrying said primary air stream, said nozzle (12) having a discharge end (30) with a reduced cross-sectional area for increasing the rate of flow of said primary air stream to induce said secondary air; and an elongated mixing chamber (14) having an upstream end (16) with a cross-sectional area larger than the cross-sectional area of said nozzle discharge end (30) for mounting in alignment therewith to carry said primary air stream and induced secondary air for mixing in said chamber (14) prior to discharge from a downstream end of the chamber (14) and on to the room or building area.

2. The apparatus according to claim 1, including a diffuser (20) coupled with the downstream end of the chamber (14) for directing said mixed air and induced secondary air into the room or building area.

3. Air handling apparatus (10) for mixing a primary air stream with secondary air prior to distribution into a room or building area, said apparatus (10) comprising:
a primary air duct (18) suitable for carrying said primary air stream from a source of conditioned air and having a downstream end; a nozzle (12) coupled with said downstream end of said primary air duct (18) and having a discharge end (30) with a reduced cross-sectional area for increasing the rate of flow of said primary air stream discharged therefrom to induce a flow of secondary air; an elongated mixing chamber (14) mounted in alignment with said nozzle discharge for carrying said primary stream after discharge therefrom, said chamber (14) having an upstream end with a cross-sectional area of said nozzle (26) discharge end, wherein the flow of said primary air stream and induced secondary air into said chamber (14) results in mixing of said primary and secondary air; and a diffuser (20)

coupled with a downstream end of said chamber (14) of discharging said mixed primary air stream and secondary air into said conditioned area.

4. The apparatus according to claim 3, wherein the discharge end of said nozzle (26) extends within the upstream end of said chamber (14) and said secondary air is induced through an annular area between the nozzle (26) outer circumference and the chamber inner circumference.

5. The apparatus according to claim 3 or 4, wherein the nozzle (26) discharge end is shaped to increase the surface area of contact of the primary air stream and secondary air at the nozzle (26) discharge end while creating a pressure drop across the nozzle (26) of approximately 0.4" : W.G.

6. Induction appratus (10) for use with an air conditioning system having a primary air duct (18) suitable for conveying primary air downstream at least a portion of the distance between a source of conditioned air and a discharge vent or diffuser (20) capable of discharging said conditioned air into a room or building area, the induction apparatus (10) comprising:
means for mixing secondary air with said primary air prior to the discharging of said primary air, said mixing means including, a nozzle (26) coupled to a downstream portion of said primary air duct (18), said nozzle having a discharge end (30) with a reduced cross-sectional area located and sized in cooperation with said primary air duct (18) to increase the rate of flow of primary air discharged therefrom, and an elongated mixing chamber (14) mounted in alignment with said nozzle (26) discharge for conveying said primary air after discharge therefrom, said chamber (14) having an upstream end portion (16) with a cross-sectional area larger than said reduce cross-sectional area of said nozzle discharge end (30) and a downstream end portion, said upstream end portion (16) and said discharge end defining a space therebetween, wherein the flow of primary air induces secondary air flow through said space with primary and secondary air directed into said chamber (14) for mixing prior to being discharged from the downstream end portion of said chamber (14) and on to said room or building area.

7. The apparatus according to claim 6, wherein the secondary air is at a higher temperature than said primary air.

8. A method for mixing in a chamber (14) a stream of primary conditioning air carried by a primary air duct (18) with secondary air carried by a return plenum prior to distribution of the mixed air within an area of a building, said method comprising the steps of:
providing a flow of said primary conditioning air through said primary air duct (18); increasing the flow rate of said primary conditioning air; inducing said secondary into said primary air stream; directing said primary air stream and said induced secondary air into said chamber (14) for mixing; and distributing said mixed primary air and secondary air into said area to condition the air therein.

9. The method according to claim 8, including the step of providing said plenum with an upstream end in communication with said room wherein said secondary air comprises return air from said room.

10. The method according to claim 8 or 9, including the step of providing a downstream end of said chamber with a diffuser (20) for distributing said mixed air into said room.

11. The method according to claim 8, 9 or 10, wherein the step of increasing the flow rate of said primary conditioning air comprises the step of passing said air through a nozzle (12) having a cross-sectional area less than the cross-sectional area of said primary air duct (18).

12. The method according to one of claims 8 to 11, including the step of providing a space between said chamber (14) and said primary air stream wherein the secondary air flows through said space and is induced into the primary air stream.

13. In an air conditioning system having a primary air duct (18) suitable for conveying primary air downstream, at least a portion of the distance between a source of conditioned air and a discharge vent or diffuser capable of discharging said conditioned air into a room or building area, the improvement comprising:
means for increasing the rate of flow of said primary air a preselected distance upstream from said diffuser (20) to induce secondary air; and means positioned between said first mentioned means and said diffuser (20) for mixing said primary air and said induced secondary air prior to discharge into said room or building area.

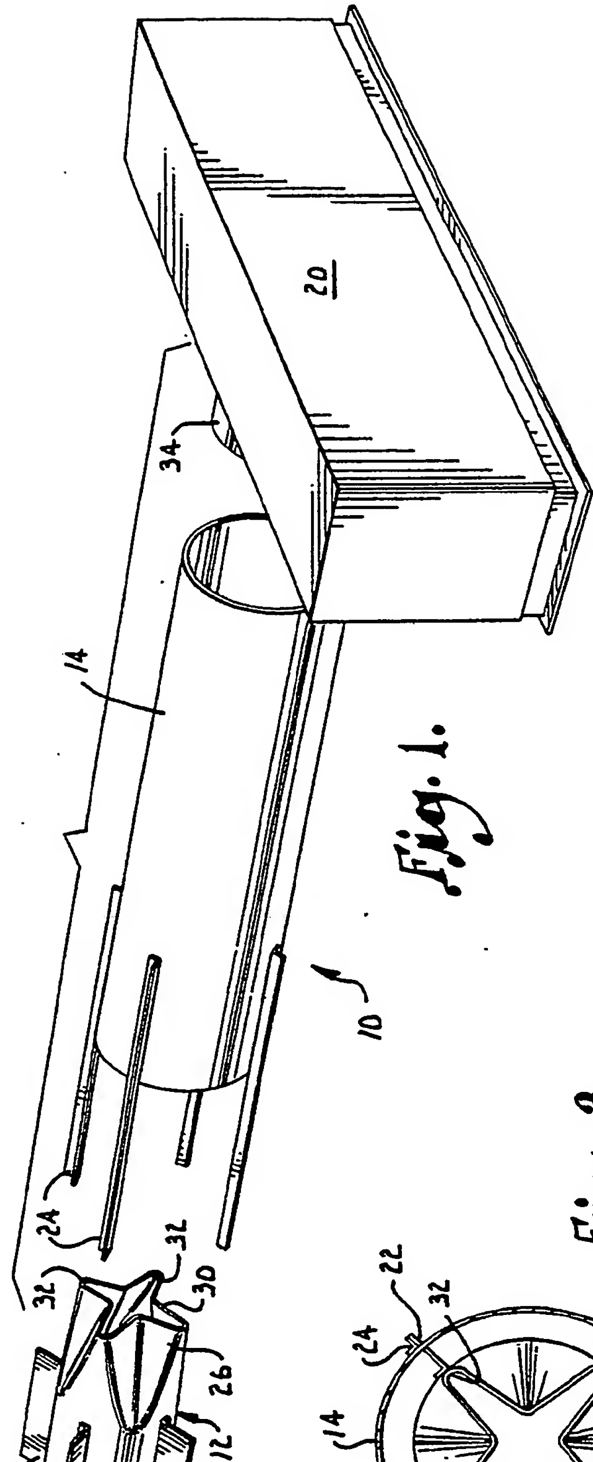

Fig. 1.

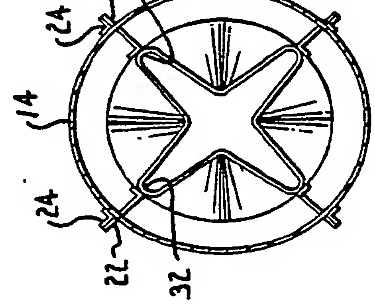

Fig. 3.

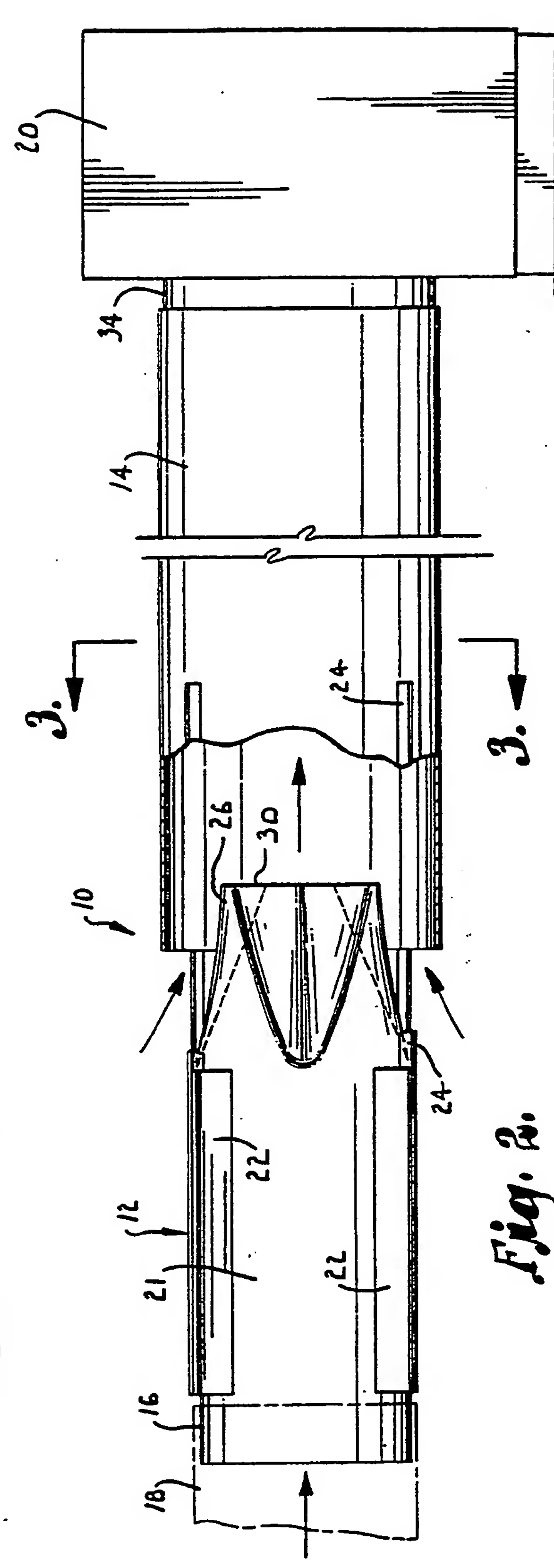

Fig. 2.

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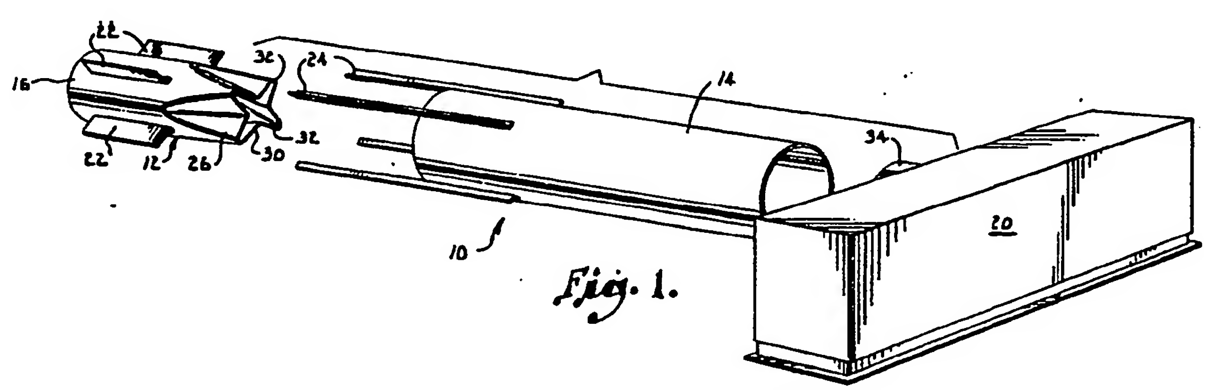

Fig. 1.

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EUROPEAN SEARCH REPORT

Application Number

EP 89 10 1377

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	FR-A-2 281 543 (INSTITUTUL NATIONAL PENTRU CREATIE STIINTIFICA SI TEHNICA) * page 1, line 23 - page 2, line 25 * ---	1,3,4,6,8,9,12,13	F 24 F 13/00 F 24 F 13/04
A	FR-A-1 235 224 (SOCIETE BERIAB) * whole document * -----	1,3,6,8,13	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

F 24 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	27-02-1990	PIEPER C

CATEGORY OF CITED DOCUMENTS

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